

# **DESIGN AND DEVELOPMENT OF WALL CLIMBING ROBOT**

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE  
AWARD OF THE DEGREE OF**

**Bachelor of Technology in Industrial Design**

**Submitted By**

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**2014**



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**CERTIFICATE**

*This is to certify that the thesis titled “**DESIGN AND DEVELOPMENT OF WALL CLIMBING ROBOT**” submitted by **Ayyagari D P Prudvi Raj (110ID0518)** and **Devidutta Nayak (110ID0570)** and in partial fulfillment of the requirements for the award of the degree **BACHELOR OF TECHNOLOGY** in **INDUSTRIAL DESIGN** at **National Institute of Technology, Rourkela** is an original work carried out by them under my supervision and guidance.*

*The matter embodied in the thesis has not been submitted to any other university/institute for award of any other degree.*

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## **ABSTRACT**

This research work presents the design of a robot capable of climbing vertical and rough planes, such as stucco walls. Such a capacity offers imperative non military person and military preferences, for example, observation, perception, look and recover and actually for diversion and amusements. The robot's locomotion is performed using rack and pinion mechanism and adhesion to wall is performed by sticking using suction cups. The detailed design is modeled and fabrication is performed. It utilizes two legs, each with two degrees of freedom. And a central box containing the required mechanisms to perform the locomotion and adhesion is designed to carry any device to perform works on wall. A model of the robot is fabricated in a workshop using general tools. This model show how the mechanisms in the robot will work and how they are assembled together.

Keywords: Wall Climbing Robot, Locomotion, Adhesion, Suction Cup, Whitworth Quick Return Mechanism, Rack and Pinion.

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# **1. INTRODUCTION**

## **1.1 Problem Statement**

A robot that can vertically and self-governing move vertically along an unpleasant surface, for example, stucco, offers extensive military and citizen points of interest. Situated high on a building, the robot, serving as a perception stage, could give significant military insights and also support in hunt and salvage operations. Such a robot could additionally be utilized for unmanned breadths of unfriendly territories and serve as a stage for convey guns and explosives. As far as non military person utilize, the robot could be utilized within development to indicator back the advancement or state of different operations being executed at hazardously abnormal amounts. Then again, there are still issues for the humanoid robots to acknowledge true human-like strolling. As of now, a large portion of the biped robots stroll with knee curved and waist drop down moving with consistent waist tallness. This firm sort of customary strolling example is ended up being more vitality devouring. Following features of the robot comes under the requirements of the robot:

- Simple Design & Portable in use.
- Light weight.
- Automatic operation while working.

## **1.2 Objective of the Work**

This task recognizes the outline and movement arranging of a robot with the capability to get on vertical surfaces. Such a proficiency fundamentally builds robot portability and workspace and has paramount military and regular person focal points. As a component of the configuration objectives, it was set that the robot ought to have the capacity to move in a self-ruling and solid way. Additionally, the robot ought to be little, minimal and simple to convey for limited-operation. To direct its missions, the robot should additionally have the capacity to remain statically joined to the divider with no vitality utilization. To attain these outline objectives, a robot was composed and created that emulates the kinematics of a human rock climber who utilizes four appendages to climb and actualizes the technique utilized by felines to jump on trees using their hooks. The robot that was composed is termed CLIBO (paw roused robot). A robot



model was developed with the end goal of showing our idea. Utilizing a kinematics display, the headway calculation that was created as a major aspect of this work joins control of the four legs with a capacity to use keen actuators. Our test effects with CLIBO have demonstrated that dependable divider-climbing is practical. The exceptional outline of the robot furnishes it with moving proficiencies, from one viewpoint, and the capacity to control its position and power appropriation, on the other.

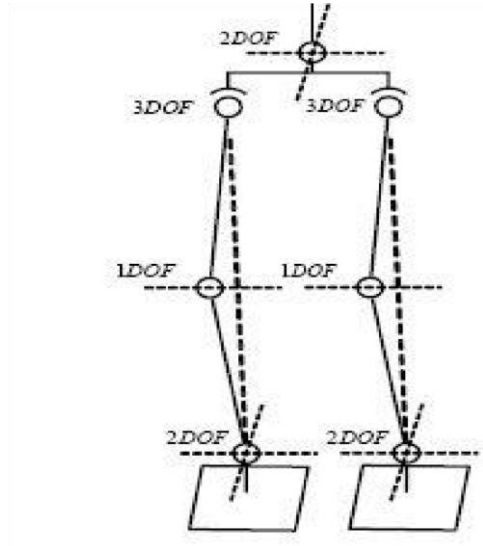
### **1.3 Background**

There are a few sorts of robots with the ability to hop on different surfaces. By utilizing cement wheel-legs for motion, the Mini-Whigs [1], a little quadruped robot, can get on smooth vertical surfaces. The Sticky bot [2] robot mimics the headway of a reptile and can get on even and smooth dividers. It ascensions utilizing directional dry glue on its exceptionally planned legs. There are a lot of people more divider-climbing robots utilizing cement systems, for example, the Geckobot [3], Waalbot [4] and a smaller than expected robot that uses a biomimetic glue [5]. Dissimilar to cement connection routines, the Clarifying Climber III [6] robot which utilizes vortex engineering and the climbing robot [7] which utilizes Bernoulli Effect, have the playing point of bond constrains generally autonomous of the sort of material and surface conditions. Then again, throughout the whole climbing process, the robots expend so much vitality that their time of operation is constrained.

#### *1.3.1 Evolution*

- Climbing robots utilizing suction are the ROBICEN [2], NINJA-II [4], ROBIN [5], a climbing robot for reviewing atomic force plants, a robot utilizing followed wheel system with suction cushions and two other four limbed robots with suction cushions appended [3].
- Attractive connection is an alternate climbing technique utilized by a few robots, for example, which utilizes perpetual attractive wheels or tracks.
- The Rise robot utilizes consistent micro spines on its feet for solid connection to harsh surfaces. However Rise utilizes about 20 (three engines as a part of each of the six legs, one in the center and one at the tail) engines for moving over huge impediments.
- These all said robots have issues, for example, lack of ability to climb harsh surfaces, substantial vitality utilization and moving limits. Contradicted to these robots, CLIBO's

outline and movement arranging empowers it to climb and move on risky surfaces and to stay static for a long time of time.



**Figure 1-Biped Mechanisms with 2 DOF**

### *1.3.2 Detailed Conception*

Cutkosky and his doctoral learner Sangbae Kim get their impulse from geckos. The lowest part of a gecko's foot is secured with billions of strands with 200-broad tips. The reptiles can adhere to any surface in view of a frail intermolecular fascination known as Van der Waals power, which acts between the fiber tips and the surface the gecko is climbing. The bond is directional: the filaments stick just when the toes drag descending, and they discharge in the inverse direction[7].

The scientists are likewise planning glue cushions that might chip away at unpleasant surfaces. The objective is to all the more nearly duplicate the nanometer-scale characteristics and the complex structure of the gecko's toe, which has edges finished with columns of nano scale filaments, each one part into considerably littler spatula-like fibers.

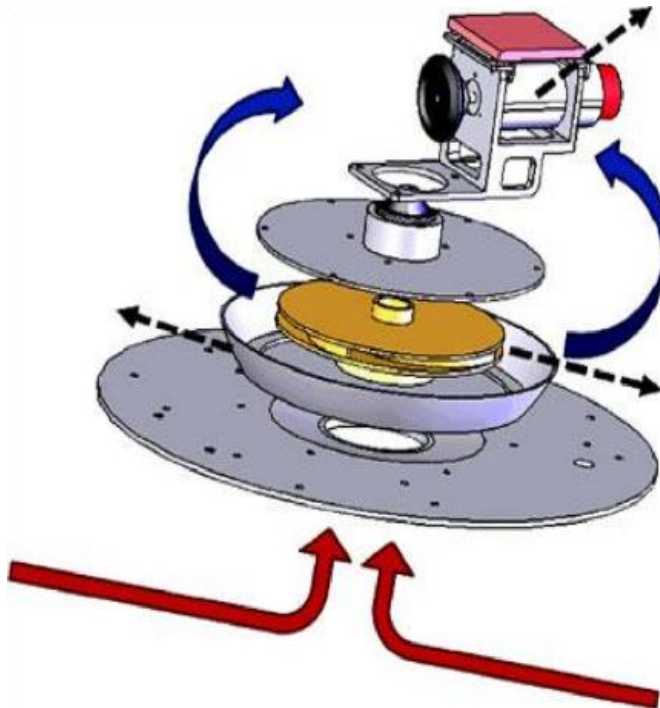
The divider climbers will need to have much stronger grip on the off chance that they are to convey sensors and transmitters for spying and observation. For the time being, Cutkosky is

considering different utilization where the size and versatility of the robot might not have to be as muddled as demonstrated in Fig.2.



**Figure 2-Spring based wall climber [1]**

The grip component is the impellent energy generator which comprises of a fundamental engine with an Impeller and a departure spread to take the let some circulation into as indicated in the Fig. 3.



**Figure 3-Exploded view of the impellent for generator mechanism [2]**

## 2. METHODOLOGY

### 2.1 Theoretical Analysis

The biped system model utilized here is a famous one as indicated in Figure 1. It has two 6-DOF legs. For each one leg, the hip joint is a round joint with three Dofs, the knee joint is a pivot joint with one DOF, and the lower leg joint is a general joint with two Dofs. At the point when the pelvis pivots in space, a 2-DOF waist joint is connected to keep up the carriage of the upper body while strolling[4].

**Table 1-Notations of Transformation [4]**

NOTATIONS OF TRANSFORMATIONS		
Symbol	Start Frame	End Frame
$T_{LF}$	Global	Left Foot
$T_{RF}$	Global	Right Foot
$T_{RF2LF}$	Right Foot	Left Foot
$T_{RF2PeL}$	Right Foot	Pelvis
$T_{PeLLF}$	Pelvis	Left Foot
$T_{pel}$	Global	Pelvis
The Notations Of $T_x$ represent the six dimensional 4*4 homogeneous transformation from the start frame to the end frame. $T_1, T_2, T_3, \dots, T^{12}$ are homogenous transformation matrices determined by D-H parameters of segments.		

The mapping from the worldwide to nearby casings of the left foot and the right foot (TLF, TRF) could be effortlessly ascertained from the arranged carriage of the feet. Hence, for each occasion, the mapping from the right foot to the left foot  $T_{RF2LF}$  might be given by:

$$T_{RF2LF} = T_{RF} T_{LF} \dots \dots \dots (1)$$

Then again, at the same occurrence, the conclusion mathematical statement of the biped component focused around the twelve joints parameters is given as:

$$T_{RF2LF} = T_1 T_2 \dots \dots T_4 T_5 \dots \dots \dots (2)$$

Example of spatial development of waist and knee joint developments are fundamental for stretch walking. The middle motivation behind two hips on pelvis is picked as the root point, and the spatial six DOF development of the pelvis is depicted by the X, Y, Z course of the root point, and 3d turns of the pelvis. Here the overall bearing is picked such that the X-center point centers send, the Z-center point centers upward, and the Y-center is picked such that a right-provided guidance schema is kept up. Regarding most of the standard biped walking, the 6- DOF spatial development of the pelvis is totally urged by giving the X, Y, Z course of root point and settling the presentation of pelvis.

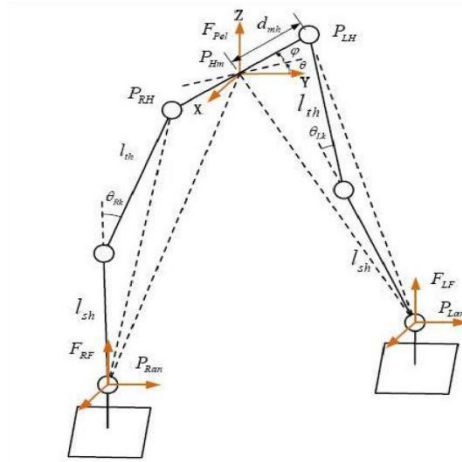
At that point, the extra compel comparison is given as take after:

$$T_{RF2PEL}=T_{RFTPEL}=T_1 T_2 ...T_3..... (3)$$

- From the comparisons above we can see that this exceptional case decouples the 12-DOF kinematic chain into two 6- DOF kinematic chains. For each one part, the joint can without much of a stretch be illuminated by explaining an ordinary six dimensional opposite issue which is generally considered. Consequently, the movement of the entire biped system is completely characterized.
- This system disentangles the reverse kinematics of the biped component. Then again, as it confines the adaptable development of waist, the reachable workspace of the pelvis is confined in a much lower level. In this way, the majority of the robots stroll in a conventional manner with their knees twisted and upper bodies drop down to verify the result of the opposite kinematics issue exist.
- On the off chance that we specifically arrange the pelvis in an elevated amount, it will be exceptionally troublesome to certification that all the arranged pelvis carriage is reachable. Hence, all the more appropriately doled out compels are required for human-like strolling example era.
- By deciding both knee joint movements, the X and Y direction of the root point and the pitch and the yaw pivot example of the pelvis, the humanoid examination gather in Waseda University understand the human-like strolling movement on WABIAN-2. In any case, for this stretch strolling movement, as both of the knee joints are obliged, it further limits the reachable workspace of the pelvis.

- Subsequently, the root point can't generally be kept up in a moderately large amount and changes a considerable measure in the vertical heading. Besides, the waist turns with an unnatural the example. Note that for human strolling, the right and left legs coordinate with one another splendidly so that the pelvis moves quickly without vast variety in the Z-course.

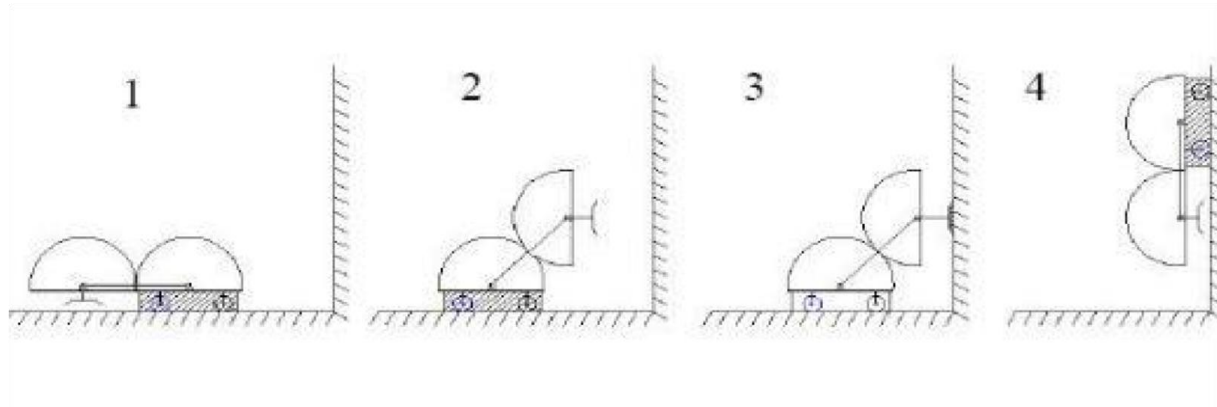
For each one time interval, the right and left knee joints are joined with each one in turn. Henceforth, if both knee joints are forced using self-rulingly chosen trajectories, the nature correspondence between them will be broken. The confinement of two knee joints will bind the pelvis at a less demanding level in the Z-heading. The legitimately allocated waist introductions will help the pelvis to keep up its tallness as waist revolution can remunerate the variety of root point in the Z-course. The waist movement of human while strolling. Here,  $\theta$  speak to the pivot of the waist along the Z-bearing (Local),  $\phi$  speak to the turn along the neighborhood X-course. Here, we apply the ZXY Euler point Sequence,  $\alpha_z$  ( $\theta$ ),  $\beta_x$  ( $\phi$ ) and  $\gamma_y$ . The algorithm approach for successful climbing is shown in Fig.4



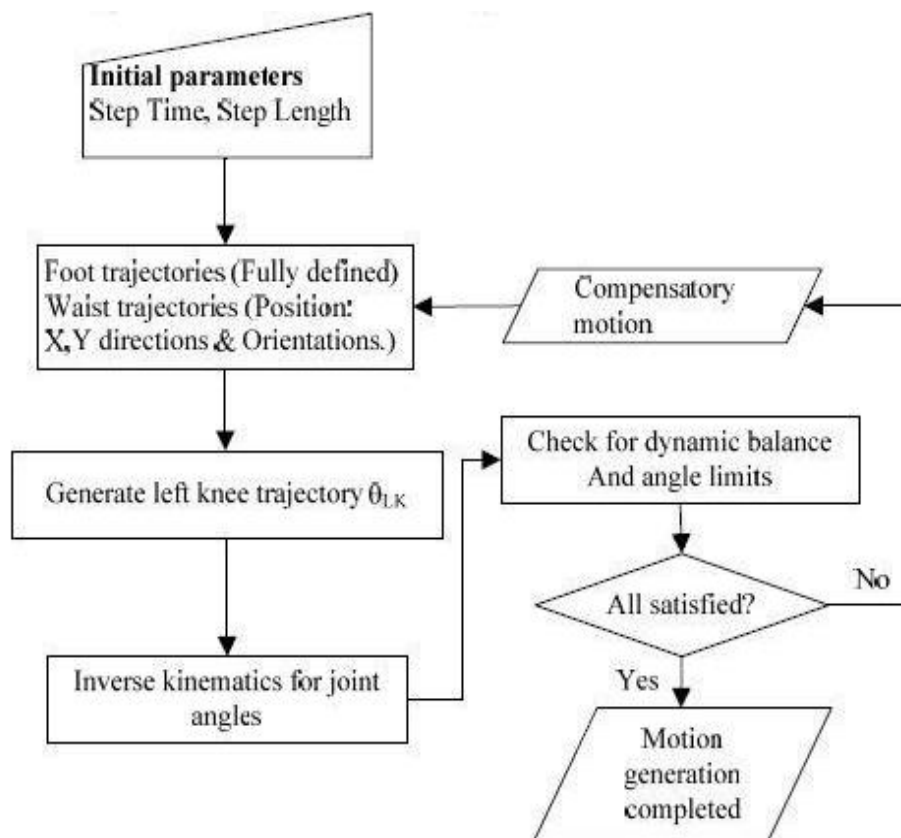
**Figure 4-Biped Mechanism**

Crossing movement is for the most part used to venture over impediments and cross between slanted surfaces, and its process is moderately entangled. The development arrangement gave in the accompanying subsections incorporates going between ground and divider and venturing over impediment on divider crossing from ground to divider. The step might be partitioned into the accompanying request, as indicated in Fig.4 (Shaded ranges demonstrate the state of adsorbing). The robot moves to a fitting spot. The robot pivots the vacuum suction module and adjusts vacuum

sucker to the target surface. The robot approaches the target surface with its vacuum sucker, when weight is secured; it shuts the radial pump, as indicated in Fig. 5.



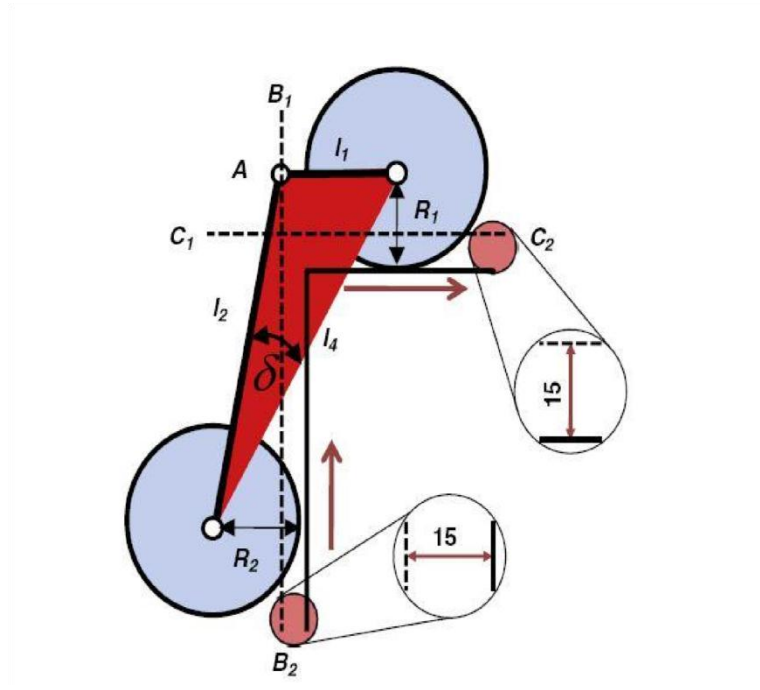
**Figure 5-Horizontal & Vertical Profile [3]**



**Figure 6-Flow Chart of Parameterization [3]**

## 2.2 Crossing from Ground to Wall

By combining two kinds of locomotive mechanisms and two types of adhesion techniques, the robot can cross between inclined surfaces easily. Experiments prove that the robot can cross from ground to a surface when the interior angle between the round and the surface is within the range of  $90^\circ$  to  $180^\circ$  and the exterior angle is within the range of  $0^\circ$  to  $20^\circ$ . A sequence of photos illustrating the robot crossing from ground to vertical wall can be seen in Fig.7. The average time needed for this process is less than 25 seconds.



**Figure 7- Ideal movement of joint**

### 2.2.1 Improvement of climbing capability via kinetic analysis

It is beneficial to note that the developments of the proposed rocker-bogie system demonstrated in Fig. 8. are not the effects of the processed powers and torques on the grounds that the proposed rocker-bogie system is in the semi-static condition. Actually, throughout the reproduction, the portable robot is put at each progressive position from the earliest starting point to the end of the step and after that, the state of semi static harmony is ascertained so that every recreation step is free from each other.



Accordingly, for a sufficiently little reproduction step, dynamical impacts, for example, speeding up for the robot body or precise quickening for the wheel could be disregarded at every recreation step. In light of this extra presumption, the energy of the proposed rocker-bogie component is carefully abused to fabricate a suitable train method for the proposed rocker-bogie system, which is concerned with the connection between the movement of the versatile robot and its causes, in particular powers and torques. In spite of the past investigation concentrating on keeping the quasistatic harmony of the proposed rocker-bogie instrument around the joint A, the minute on each one wheel is acknowledged to escape from the circumstances where the versatile robot can't climb the stair and ends where it is a direct result of slip. It is indicated in Fig. 8

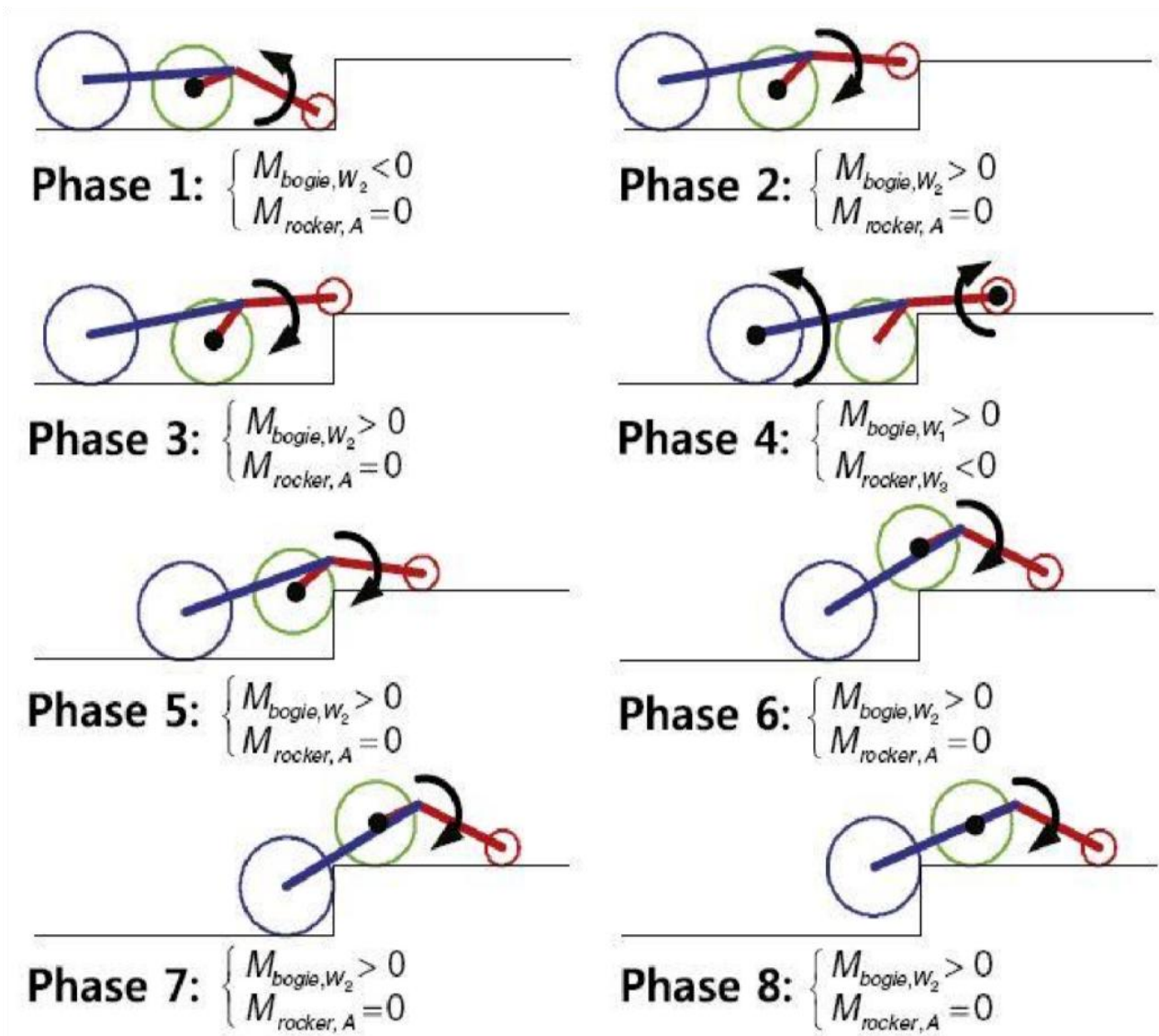
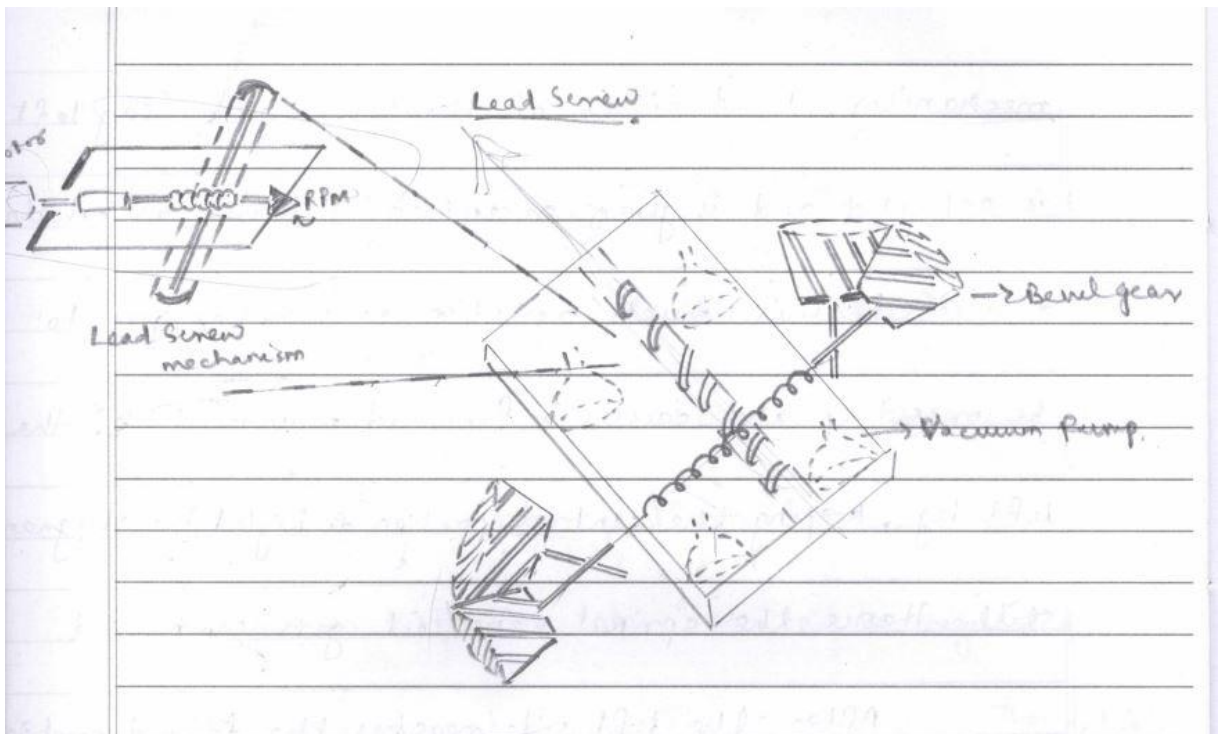


Figure 8-Kinetic conditions with respect to each climbing phase for the type I stairs [3]

## 2.3 Concept Designs

### 2.3.1 Design 1

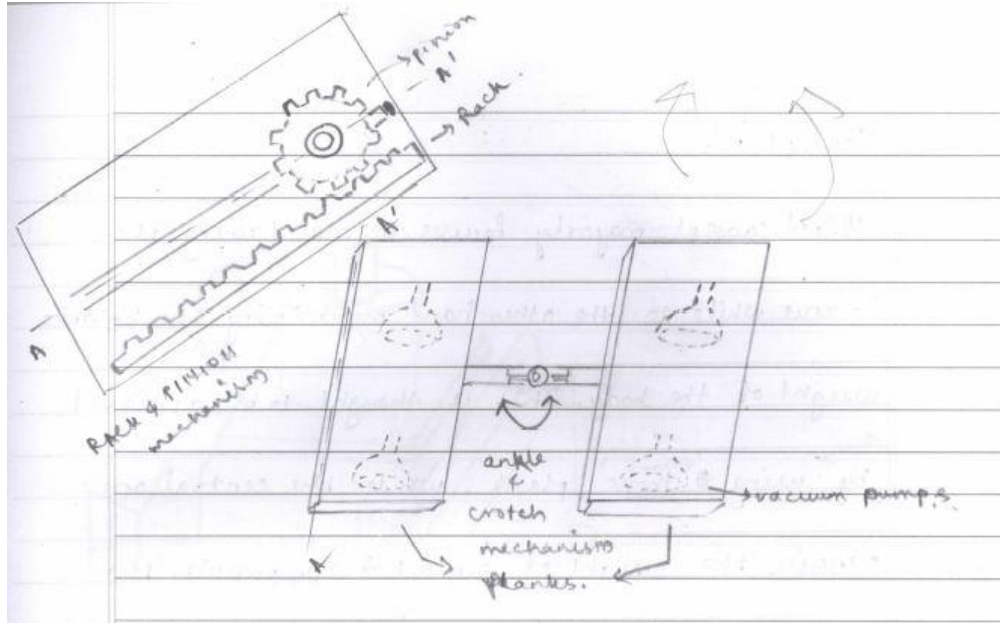
- Bevel gears are used for delivering motion using Servo motors and spring mechanism is used for coupling the two vacuum cups.
- Advantage is the use of bevel gears ensures higher sophistication in motion and also high performance.
- Disadvantage is more complexity in design and higher cost.



**Figure 9-Concept 1**

### 2.3.2 Design 2

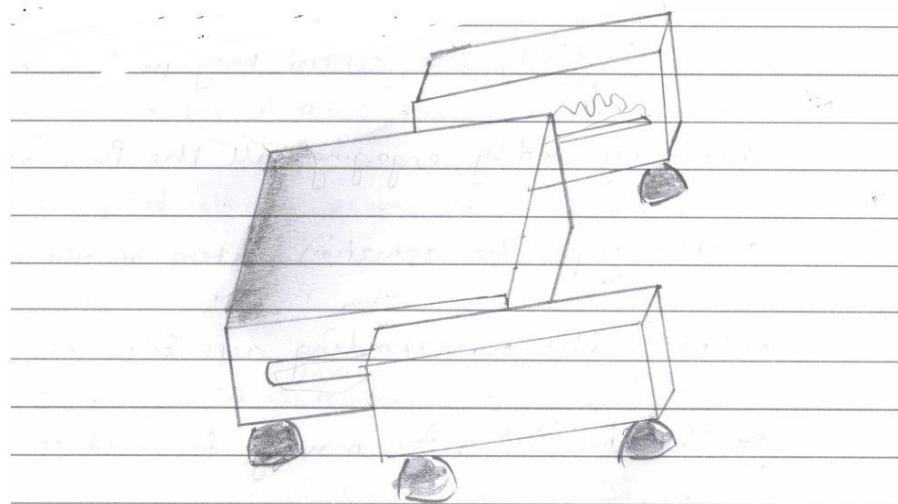
- Using single Rack and Pinion Mechanism and suction Cups.
- Advantages are low cost due to simple design
- Disadvantages are weight imbalance as it is concentrated in one side.



**Figure 10-Concept 2**

### 2.3.3 Design 3(Final concept design)

- Using two rack and pinion assemblies for locomotion and suction cup for adhesion.
- This has separate central box which carries the tooling device while climbing up.
- Advantages are diversifying the central body gives stability to whole body also simpler in design and less cost.
- As compared to rest two models more stability is ensured in Concept 3 for its simpler design in less cost.



**Figure 11-Concept 3**

## **2. MECHANICAL SYSTEM**

### **3.1 Overview**

The robot to its available structure lived up to expectations bunches of progressions. We began planning our robot remembering CLIBO divider climbing robot. Numerous constraints because of the non-accessibility or money related limitations came our direction and we continued changing our plan so we could make a model from neighborhood assets. Our divider climbing robot is two legged having two suction measures on each one leg and utilization suction method to adhere on to the divider. Likewise the fundamental some piece of the robot is the Central box (collection of the robot) which conveys the obliged apparatus up the divider. Parts like DC engine, Vacuum pump and so on are kept inside this crate. It is intended to remembering the lesser weight. A solitary actuator moves the robot and fundamental vacuum pump of light weight is utilized to make obliged weight for containers to adhere to divider.

### **3.2 Different Techniques to Stick Robot onto Wall**

A standout amongst the most testing assignments in climbing robot outline is to create a legitimate grip component to guarantee that the robot sticks to divider surfaces dependably without giving up versatility. After audit of the aforementioned writing and there created models we inferred that So far, four sorts of grip methods have been examined

- Magnetic devices for climbing ferrous surfaces.
- Attraction force generators based on aerodynamic principles.
- Bio-mimetic approaches inspired by climbing animals.
- Vacuum suction techniques for smooth and nonporous surfaces.

Attractive bond gadgets are most guaranteeing for robots moving around on steel structures. Robots utilizing changeless magnets or electromagnets could be found for climbing extensive steel structures for inward review of iron channels. In any case, their requisitions are restricted to steel dividers because of the way of magnets.

Choosing to create attraction force based on aerodynamic principles including the use of propeller is a complex task. Robots which create attraction force based on aerodynamic principles have demonstrated the capability moving on brick and concrete walls with considerable success. Then

again, the force utilization and commotion are two issues need to be tended to for some reconnaissance assignments. Keeping in view that all the materials are accessible in business, utilizing the system of the propulsive energy was not conceivable as there are no merchants to make a definite propeller of obliged particular.

Dry glue called geckos is manufactured polymers intended to copy the properties of setae. Setae are the commonly happening glue in the feet of reptiles which empower them to climb very nearly all sort of surfaces. The capacity of geckos to jump on sheer surfaces has been ascribed to van-der-Waals power. Van-der-Waals energy alludes to the alluring or awful compels between particles (or between parts of the same particle) other than those because of covalent bonds or to the electrostatic communication of particles with each one in turn or with impartial atoms. It is additionally off and on again utilized inexactly as an equivalent word for the totality of intermolecular strengths. Van-der-Waals strengths are moderately feeble contrasted with typical synthetic securities, however assume a basic part in numerous fields. A late study proposes that water particles of harshly monolayer thickness (introduce on all surfaces) additionally assume a part. All things considered, a gecko can cling a glass surface utilizing one and only toe. Exertions keep on creating a manufactured "gecko tape" that adventures this information. As such, research has processed some guaranteeing effects - early research yielded a sticky tape item, which just gets a small amount of the powers measured from the regular material, and new research are, no doubt created with the objective of emphasizing 200 times the cement strengths of the characteristic material.

In provisions for non-ferromagnetic divider surfaces, climbing robots most by and large utilize vacuum suctions to handle the grip energy. We pick suction measures as the strategy to adhere our robot to the divider is simple with containers and they are of light weight as they are made of plastic or elastic materials.

### 3.3 Mathematical Calculations [5]

The robot is backed on the divider with a vacuum mug. There is a weight contrast between within the glass and outside. This weight distinction processes the energy which holds the container and therefore robot on the divider.

The force is given as

$$P_{at} - P_{in} = F/A \dots\dots\dots (4)$$

Where  $P_{at} \rightarrow$  Atmospheric Pressure  
 $P_{in} \rightarrow$  Pressure inside Vacuum Cup  
 $A \rightarrow$  Area of Vacuum Cup

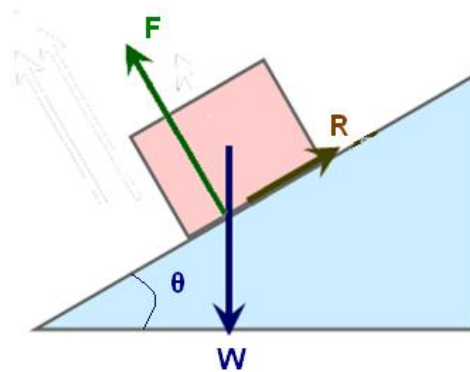
$$F = (P_{at} - P_{in})A \dots\dots\dots (5)$$

The force which does not let the cup slide on wall is frictional force.

$$R = \mu F \dots\dots\dots (6)$$

Where  $F \rightarrow$  Reaction Force  
 $R \rightarrow$  Frictional Force  
 $\mu \rightarrow$  Coefficient of Friction between Pad and Wall, it depends on the materials of Wall and pad

Forces acting on the robot are shown in a free body diagram below



**Figure 12- Forces acting on a Suction Cup [8]**

$$R = \mu F = \mu (P_{at} - P_{in}) A$$

$$R = W \cos(90-\theta)$$

$$R = W \sin\theta$$

$$W \sin\theta = [\mu(P)_{at} - P_{in}]A$$

$$W = ([\mu(P)_{at} - P_{in}]A) / (\sin\theta) \dots\dots\dots (6)$$

Where  $W \rightarrow$  Weight of Robot  
 $\theta \rightarrow$  Angle of Inclination

The change in volume to make obliged weight might be figured from the accompanying counts

$$P_{in} V_1 = P_{at} V_2$$

$$P_{in} = P_{at} V_2 / V_1 \dots\dots\dots (7)$$

Where

$P_{at} \rightarrow$  Atmospheric Pressure  
 $P_{in} \rightarrow$  Pressure inside Vacuum Cup  
 $V_1 \rightarrow$  Volume at  $t = \max$   
 $V_2 \rightarrow$  Volume at  $t = 0$

Presently the separation of middle of gravity from the mugs differs .The containers underneath the focal point of gravity obliges less compel than the glasses over the core of gravity to keep the robot fixed to the wall.

$$W \cdot h + F_1 d_1 + F_2 d_2 + F_3 d_3 + F_4 d_4 = 0 \dots\dots\dots (8)$$

$$W \cdot h = -(F_1 d_1 + F_2 d_2 + F_3 d_3 + F_4 d_4) \dots\dots\dots (9)$$

Where  $d_1, d_2, d_3, d_4$  Are the distance from centre of gravity to the centre of the respective vacuum cups.

Suppose the distance of cups from centre of gravity is same then above equation becomes the following equation.

$$= -(F_1 + F_2 + F_3 + F_4) d$$

The glasses over the centre of gravity are at same tallness from middle of gravity so the strengths following up on these mugs could be included. Likewise compels following up on the containers beneath the inside of gravity might be included. Hence

$$F_1 = F_2$$

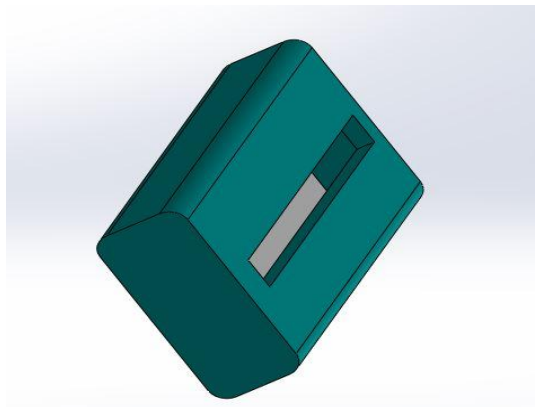
$$F_3 = F_4$$

$$W \cdot h = -(2F_1 + 2F_3) \cdot d \dots \dots \dots (10)$$

As it may be seen from graph that constrains  $F_1$  and  $F_2$  act backwards to the vitality made by the vacuum in the vacuum glass while  $F_3$  and  $F_4$  act along the force made by the vacuum in the vacuum glasses. For the determination of the holders of proportional width the force catching up on the mugs over the center of gravity must be recognized.

### 3.4 Mechanical Structure

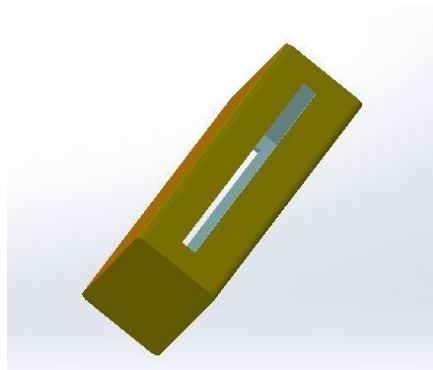
#### 3.4.1 Legs



**Figure 13- Leg Container Box**

These are one of the important part of our robot used for balancing, movement of the robot. It contains the Rack and Pinion mechanism inside it. It also contains a slot which allows the shaft connecting the Pinion and Motor. There will be two legs on both sides of the Central box (body of robot) and they both are symmetric to each other.

#### 3.4.2 Central Box



**Figure 14- Central Box**



This is the body of the robot which carries the required tooling devices on it while climbing the wall. It contains parts like DC Motor, Vacuum Pump etc. inside it. It has two slots on either side of it to allow shafts to pass through them.

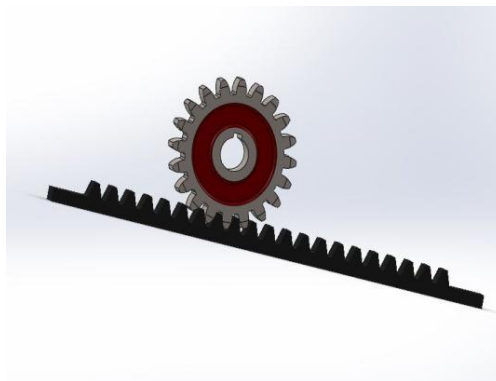
#### *3.4.3 Suction Cups*



**Figure 15- Suction Cup**

These are the feet of the legs which help to stick to wall rigidly. These are made up of rubber or plastic. They stick to almost any surface which is even and non porous when pressure is applied against the upper part of it or the air inside it is sucked out. There will be eight cups in this robot four of them are under the Central box at each corner of it and two are attached to the each leg at the end. We are using a bit smaller cup in size and more cups so as to compensate the balance and also avoid slipping if any of them failed to stick to wall as the rest of them will stick to wall.

#### *3.4.4 Rack and Pinion*



**Figure 16- Rack and Pinion**

This is the driving mechanism helps move the robot forward. It is actuated by a DC Servo-motor which is present in Central box via a shaft. There are two rack and pinion assemblies inside each leg.

#### *3.4.5 DC Servo Motor*



**Figure 17- DC Motor [10]**

It utilizes Servo system utilizing positive input control. Here accuracy of rigging revolution is greatly required which could be made accessible just by utilizing servo engines. The order is given to it by controller which gives sign for particular turn plot. For giving summons for forward and retrogressive turn, encoders are introduced on the focal body. This current engine's pole is associated with both pinions and makes them pivot and henceforth the legs make headway. A movement in converse heading and settling the legs to the divider makes the Central box to advance. Two engines will turn two pinions in same way.

#### *3.4.6 Syringe*

A syringe nowadays nearly always means a medical syringe, but it can mean any of these:

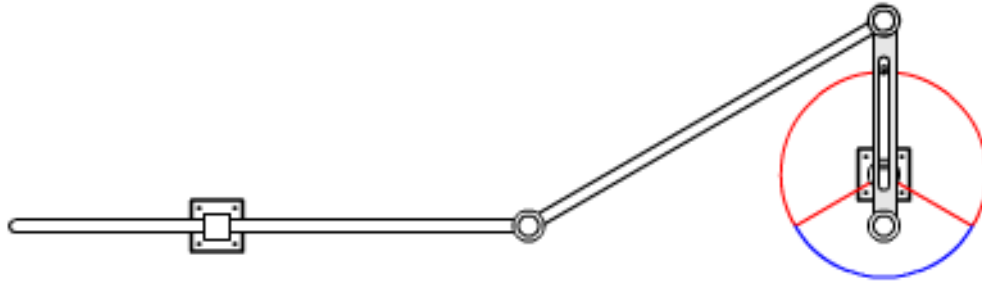
- A basic hand-controlled cylinder pump comprising of a plunger that could be pulled and pushed along inside a barrel shaped tube (the barrel), which has a little opening toward one side, so it can suck fluid in and afterward squirt it out by the same gap. The expression "syringe" originated from the Greek word signifying "tube" by means of concentrating another independent from its Greek-sort plural "syringes".
- In former times the word "syringe" also meant big two-handed pumps of this type used e.g. as early firefighting water pumps.

- These days the saying "syringe" is confined to more diminutive gadgets, used to exchange little measures of fluids or gasses to or from generally out of reach regions, including especially hypodermic syringes utilized with a needle for infusion.
- As a result, jet injectors are sometimes called syringes.

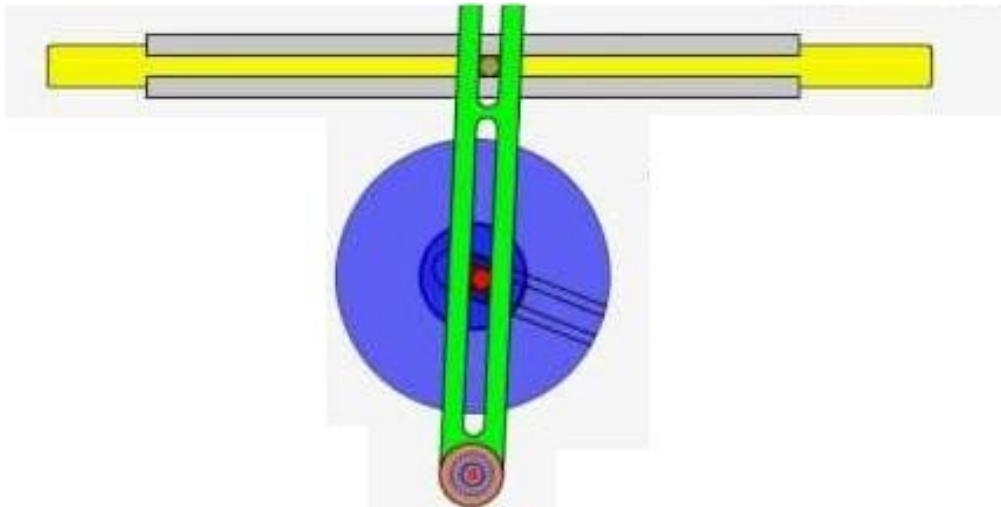


**Figure 18- Syringe [11]**

Here in our project, two syringes are used for creating vacuum required to attach suction cups of both central box and also legs of the robot. We used syringes as the vacuum pump to generate vacuum required for suction cups is unavailable in market. Generally vacuum pumps will be available in bigger sizes and which will be heavy, costly and more than the required capacity of the robot. Two syringes are used similar to two way piston one of which provides vacuum for central box's suction cups when it is attached to wall while other syringe is kept non functional. The plungers of both are connected to each other and the connection is attached to wooden piece (in our fabricated model) which moves to and fro in a linear slot. It is operated by Whitworth quick return mechanism, which is clearly explained below.



**Figure 19- Whitworth Mechanism Line Diagram [12]**

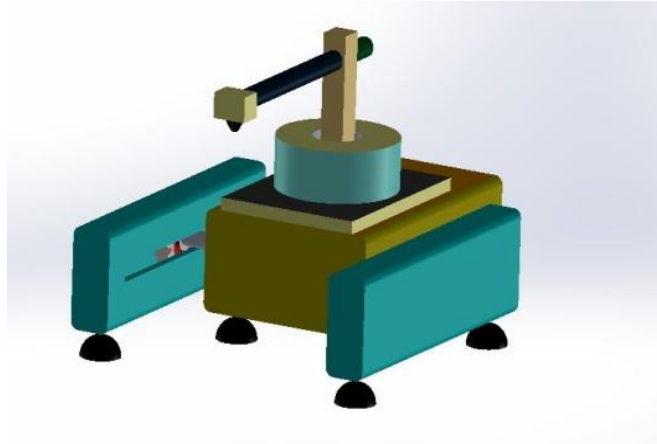


**Figure 20-Whitworth Mechanism Physical Model [13]**

This system is made of a driving wrench and of a driven slider wrench. In the acknowledged design, the settled turn of the driven wrench is placed within the loop on which the end of the driving wrench moves. This prompts a persistent movement of the slider wrench. The design where this turn is placed outside the ring on which the end of the driving wrench moves is recognized in. An engine which could be controllable by the controller turns the roundabout circle which further moves the complete system.

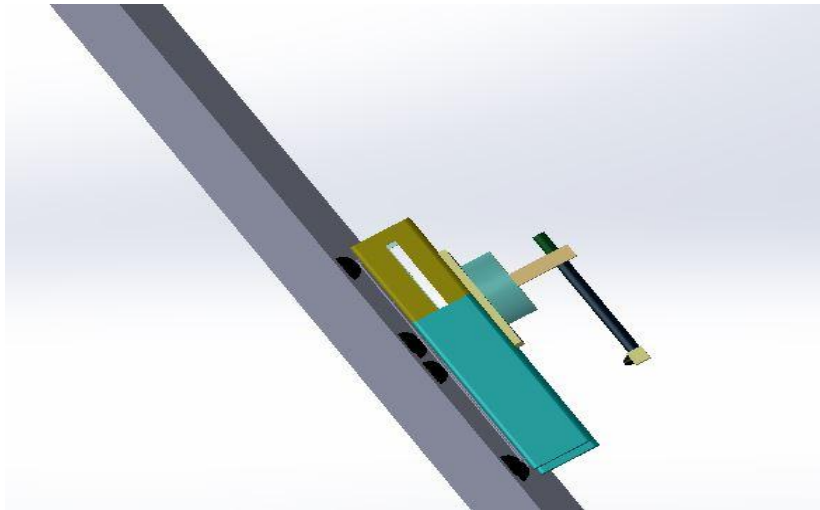
#### 4. ASSEMBLY AND FABRICATION

The final Design of the robot with a tooling device on it is modeled in SOLIDWORKS.



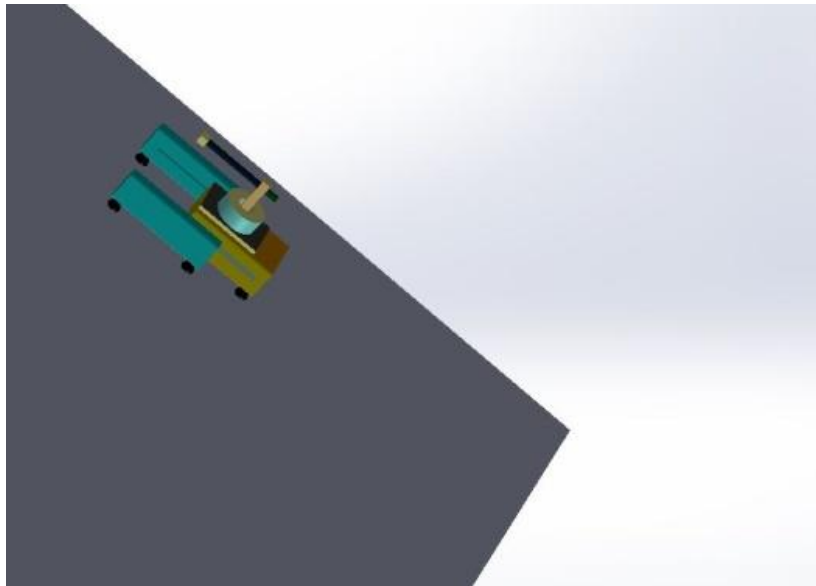
**Figure 21-Final Assembly**

Final assembly includes all the parts mentioned in chapter 3.4. All the parts are assembled in accordingly using several assembling mechanisms like screwing, adhesion etc. and the power required for operating all the three motors is supplied by a battery inside the central box. The structure above the central box in this image is any tool which is carried by the robot.



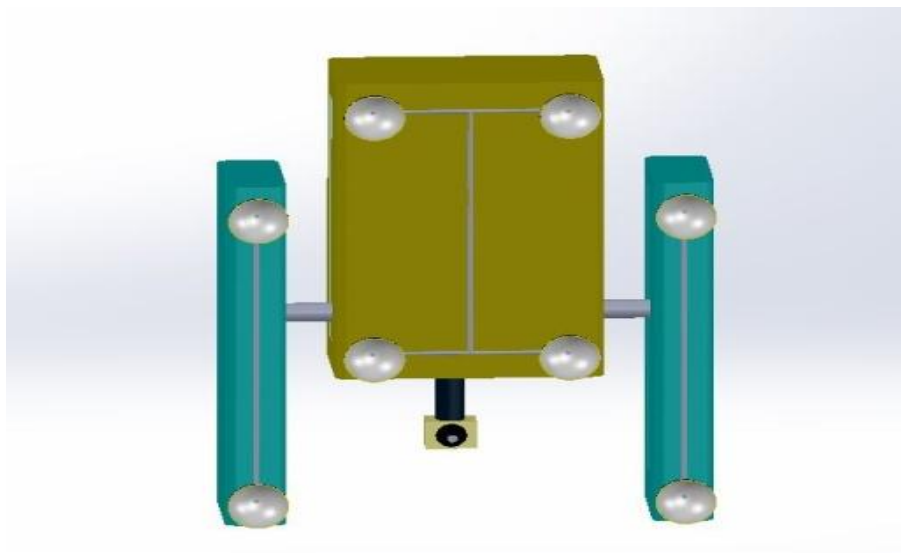
**Figure 22- Robot Climbing Slanted Wall**

This image shows how the robot carrying a tool, climbs a slanted surface from a side view



**Figure 23- Robot Climbing Slanted Wall (Top Angle View)**

This image is another view of the robot climbing the wall. The tool (E.g. Painting tool, Vacuum cleaner etc.)

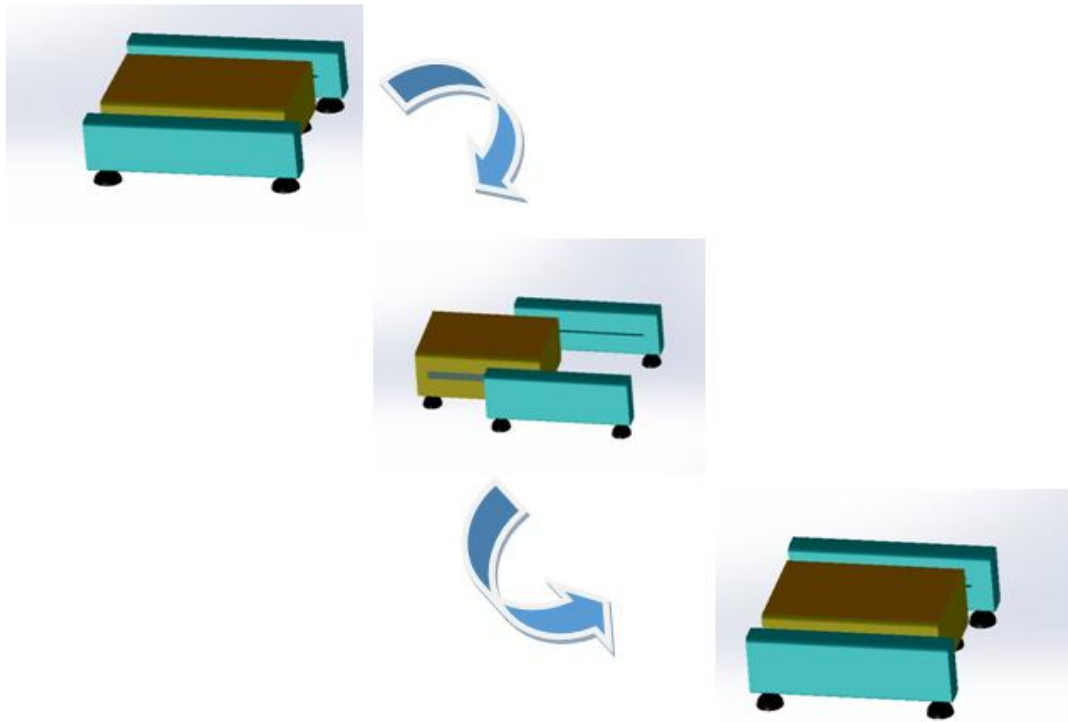


**Figure 24- Robot Bottom View**

This image shows the bottom view of the robot showing how the suction cups is arranged, how they are connected with the pipes which supply the vacuum to the cups.

## 4.1 GAIT OF ROBOT

Initially the robot will be placed against the wall which it has to climb. At first the Central box which has four suction cups beneath it are activated and they make the robot stick to wall. The legs are free to move in this position. Now the motor starts rotating shaft in clockwise direction which moves rack and hence the leg in forward direction. It moves forward till the pinion reaches end of the rack. At this stage suction cups under the legs of robot are activated and sticks to wall. Then the suction cups below the Central box are released. Now the motor is activated such that it rotates the shaft in anti clockwise direction and hence the pinion moves towards the initial end and the Central box which is fixed to motor will move up matching the initial position but at one step away from starting point.



**Figure 25- Gait of Robot**

The above figure has three positions of the robot which shows the gait of the robot according to above description.

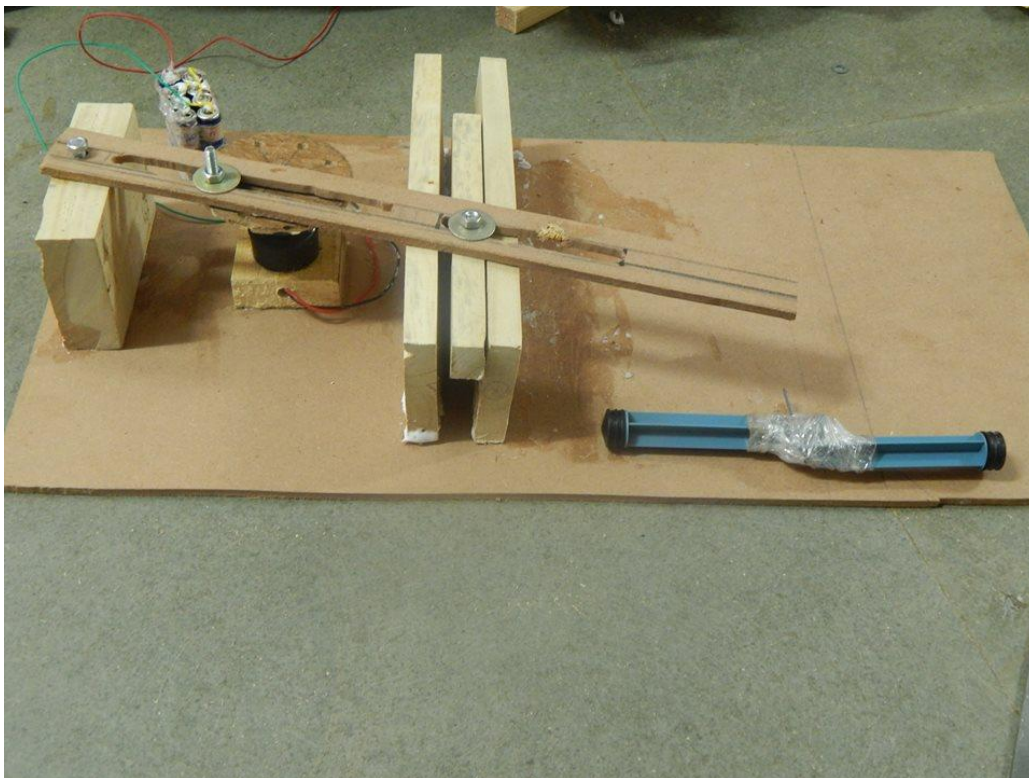
## 4.2 FABRICATION

A physical prototype is being fabricated by using low cost, low weight materials which are available in market to give a rough idea of how the robot will be and how it will work.

**Table 2-Parts Used for Fabrication.**

<b>Part No.</b>	<b>Part Name</b>	<b>Materials Used</b>	<b>Manufacturing Method</b>	<b>Specifications</b>	<b>No. of Parts</b>
1	Central box Platform	Wooden plank	Manual operations	30*60*0.5 cm 30*10*0.5 cm 60*10*0.5 cm	6
2	Legs	Wooden Plank	Manual operations	20*10*0.5 cm 10*3*0.5 cm 20* 3*0.5 cm	12
3	Rack	ABS	3D printing	15.6* 1*1.6 cm	2
4	Pinion	ABS	3D printing	4.4 cm Ø, 1 cm	2
5	Syringe	Plastic	-	20 ml	2
6	DC Motor	-	-	150 RPM	3
7	Battery	-	-	1.5 volts	8
8	Suction Cup	Rubber	-	4cm Ø	8
9	Whitworth Mechanism	Wooden Planks	Manual Operations	-	4





**Figure 26- Fabricated Model**

## **5. CONCLUSION**

This simpler, compact and lightweight robotic platform provides a safe and effective means to deal with hazardous duty operations. Within the mechanical area our robust platform, it is developed to climb on relatively smooth surfaces. Various work related instruments or tools such as painting tools, cleaning tools, drilling tools etc. can be mounted on it to carry up on wall. The working model of Wall Climbing Robot is modeled and assembled in SOLIDWORKS version 13.0. A simulation is to be generated to show its working.

In the prototype, the whit worth quick return mechanism in which the circular disc connected to driving crank is connected to a motor which operates the disc to initiate the motion required for the syringes to create vacuum and two motors connecting to the pinions which lies inside the legs of the robot to perform locomotion is shown. And this prototype is fabricated using several materials as shown in Table 2 (Chapter 4).

### **5.1 FUTURE SCOPE**

- A controller is to be designed to control the robot.
- Further improvements like appropriate mechanism for turning the robot, performing lateral motion can be implemented.
- Protototype of this Robot can be made in a robust way and test run can be performed for performance and cost analysis.
- Building up the physical model by considering the results of testing phase.
- Further analysis can be focused on how to detect obstacles and generate path while moving upward. This requires artificial intelligence.

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